Innovation performance of Russia's northwestern regions: a comparative evaluation

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THE ECONOMY OF THE NORTH-WEST PART OF RUSSIA

INNOVATION PERFORMANCE OF RUSSIA'S NORTHWESTERN REGIONS: A COMPARATIVE EVALUATION

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Innovative activities underpin the economic development and competitiveness of Russian regions. This article seeks to compare the innovation performance of Russia's north-western regions, which are among the most progressive in the country, and their available resource. A review of the literature suggests that most Russian publications combine systems of composite indices with econometric and statistical approaches to evaluate regional innovation performance. The same methods are employed in this study. Comparative analysis indicates significant differences between the regions in both available resource and innovation advancements. Juxtaposing composite resource availability indices and innovation performance aided in devising a typology of regions and analysing changes in the position in a composite evaluation matrix. The findings demonstrate that Saint Petersburg and the Leningrad region comfortably outperform the other northwestern regions in innovation. Regression and correlation analysis reveals that innovation performance depends crucially on earlier achievements and currently available resources. The Novgorod region, however, is making headway without a marked change in the level of resources. Thus, it is important to transfer innovations designed in resource-rich regions to their less well-off counterparts to achieve positive synergy throughout northwest Russia.

Keywords:
innovations, innovative development, innovative activity, composite indicator, integral index, interregional comparisons, regional economy

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Introduction

In recent years, an extensive body of literature has been devoted to the study of innovation development (ID) and innovation activity (IA). Innovation has been regarded as an essential condition for the accelerated progressive development of countries and regions. It is important to note that large-scale innovations in the regions of the Russian Federation is one of the key factors for ensuring the homogeneity of the country's economic space, increasing competitiveness and strengthening the international position of Russia. To stimulate innovation activity, the country's authorities use a number of measures — free access to scientific and technical information, the development of international and interregional scientific and technical cooperation, the creation of equal opportunities for participants in innovation at different levels, financing innovative development and implementing entrepreneurship support programmes, etc. The impact and effectiveness of these measures remain debatable. Innovation effectiveness is traditionally evaluated by comparing the planned and actual results achieved and innovation efficiency is measured by comparing the results with the resources spent. In their assessment of innovation effectiveness, authors study the problem of investment concentration, labour resources and the results achieved by certain regions of the country and a decrease in innovation activity in other regions [1, 2]. When assessing the efficiency of innovation, scholars often note the absence of an connection between the provision of resources and the results of innovation activity in Russian regions [3].

This study hypothesizes that the results of innovation activity in the selected regions of Russia (compared to other regions) largely depend on the provision of resources and the earlier obtained results. This idea emphasises the importance of targeted management of innovative regional development. This study aims to assess the efficiency and effectiveness of innovation activity in the regions of the North-West Federal District, which is one of the key districts of Russia in terms of its innovative potential, research base and proximity to the largest global markets.

Review of methods for assessing innovative development and innovation performance

Russian researchers interpret innovative development as a continuous use of the results of scientific and technological activities for the sustainability of economic agents and the creation of innovative goods and services as well as their production and application [4]. Within the process approach, innovative development is considered as cost increasing since it includes the modernisation of the existing and the construction of new production facilities, production-oriented scientific and technical activities and the development of infrastructure [5].

The overview of scientific literature over the past ten years has made it possible to identify the most common methods for assessing innovation activity and innovation development. In their works, many Russian and foreign authors use a system of complex integral indices [6—13; 11, p. 327—328; 12, p. 70—71; 13—15]). The method of integral assessment is also used in the regularly published *Ranking of Innovative Development of the Subjects of the Russian Federation* [16]. In addition, integrated assessment is used in the calculation of the *European Innovation Scoreboard* (EIS) European ranking[1]. There are also very specific methods of integral assessment, for example, the estimation of the innovative activity of regions based on creativity (indices of innovativeness) [17; 18].

It is worth noting that sets of indicators for calculating indices and rankings of innovative development differ significantly from one researcher to another researcher, depending on what goals they pursue. Econometric and statistical analyses, as well as data envelopment analysis (DEA) are often employed to evaluate IA and ID [19; 23—31].

When using methods of integrated assessment, the statistical and econometric analyses of ID and IA of the regions of Russia, authors usually turn to the same statistical database. Consequently, many authors opt for similar sets of key indicators and the results obtained are often quite comparable.

To evaluate the ID and IA of Russian regions scientists employ such indicators as the costs of technological innovations, internal costs of research and development, the number of employees engaged in research and development, the amount of innovative goods, works and services, the number of developed and used advanced production technologies, as well as the number of patents and licenses issued. In addition, researchers often include indicators related to the use of information and communication technologies (Internet use, data transfers, etc.).

This study proposes a method of integrated assessment of the IA of the region of the North-Western Federal District (NWFD). The method includes statistical and econometric analyses used for the comparative evaluation of the IA of the regions, for determining the factors which proved to be relevant for achieving IA results as well as for identifying the extent to which the regions used their available resource potential.

[1] The European Innovation Scoreboard.

Methods of research

Based on official statistics[2], a set of indicators was selected to analyse the IA of the regions in terms of the resources involved and the results achieved. To minimize the distorting effect of inflation, all value indicators were expressed in fixed prices (the prices of 2019). To ensure the comparability of the data in the regions, which differ considerably in their territory, either relative indicators (%) or standardized indicators reflecting the distribution of an innovation per 1,000 or 10,000 people have been used. The composition of the selected set of indicators was determined based on the results of the review of the main indicators used for the assessment of the innovative development of the constituent entities of the Russian Federation [32]. Innovation activity (IA) in the regions is carried out within the framework of a regional innovation system, exploiting various types of resources, which are turned into different types of innovation-based products resulting from innovation activities[3].

In this study, the provision of resources for IA was assessed by measuring the costs of intellectual, labour, financial and information resources employed. The following indicators were used: the number of research and development organisations per 100,000 population; the number of staff engaged in research and development per 1,000 population; the number of postgraduate students per 10,000 population; the number of doctoral students per 100,000 population; the costs of technological innovations per 1,000 people; internal research and development costs per 1,000 population; advanced production technologies per 1,000 people; the percentage of organisations using information and communication technologies.

The following indicators were employed for assessing the results of IA (products created during its implementation): the amount of innovative goods, works and services per 1,000 people; the number of patents issued per 10,000 people; advanced production technologies developed per 100,000 people; the number of agreements for the export and import of technologies and technical services per 1,000 inhabitants; the number of high-productivity jobs per 1,000 population; the number of postgraduate students who graduated from university after defending their thesis per 10,000 people; the number of doctoral students graduating from doctoral studies after the defending their per doctoral thesis per 100, 000 people of the population.

[2] *Regions of Russia. Socio-economic indicators. 2019*, 2019, stat. reset / Rosstat. Moscow.

[3] Inputs are commodities or services used to produce goods and services. An economy uses its existing technology to combine inputs to produce outputs. Outputs are the various useful goods or services that result from the production process (Samuelson P. A., Nordhaus W. D. Economics. — New York: McGraw-Hill Companies, 2010. — P. 9).

All indicators were subject to normalization by applying the indicator value in a given region to the average indicator value in the NWFD as a whole:

$$N.val. = \frac{Indicator\ value\ of\ a\ region}{Average\ indicator\ value\ for\ the\ NWFD} \quad (1)$$

The normalized value characterizes the level achieved by the region compared with the average level achieved in the NWFD as a whole. In this approach, the average value of the NWFD serves as a benchmark or comparison base. In the case when the N.val. is higher than 1, the level achieved in the region is higher than the NWFD average. Otherwise, it is lower than the NWFD average.

Then, according to the arithmetic average formula, the integral index of the provision of resources was calculated for input indicators and the integral index of innovation results for output indicators:

$$Input\ I. = \frac{(I1 + I2 + I3 + ..In)}{N}, \quad (2)$$

$$Ouput\ I. = \frac{(I1 + I2 + I3 + ..In)}{N}, \quad (3)$$

where Input I. is the integral index of ID resource provision; Output I. is the integral index of ID results; I_1, I_2, I_3..., In is input or output indicators; and N is the number of key figures.

Integral indices characterize the general level achieved in the region, compared to the average in the federal district. If the value of the integral index exceeds on, then the level achieved in the region (by resource provision or ID results) is generally higher than the average for the Federal District. Otherwise, it is lower than the Federal District average.

When calculating these indices, the indicators used were considered to be of equal importance. This allowed avoiding the subjectivity observed when using expert assessments for establishing the significance for each indicator.

Combining the integral input and output estimates made it possible to apply the matrix method and identify certain types of regions in accordance with the quadrants of the matrix (fig. 1).

Output I. *Higher than in FD* 1,0	**Quadrant II** Imbalance in ID processes — high performance with low resource provision	**Quadrant III** Balance of resource provision and high-level impact of ID
Lower than in FD	**Quadrant I** Balance of resource provision and impact of ID at low level	**Quadrant IV** Imbalance in ID processes — low performance with high resource provision
	Lower than in FD 1,0	*Higher than in FD* Input I.

Fig. 1. Integrated Assessment Matrix of the IA of the Region

The comparison of integral performance estimations and resource provision allows calculating the index of conditional efficiency of IA of the regions (EI), which characterizes how many conventional output units (IA results) are per one conditional input unit (resources spent on IA):

$$EI = \frac{Output\ I.}{Input\ I.}, \tag{4}$$

where, EI is the index of conditional efficiency of the region's IA.

If the value of the conditional efficiency index exceeds 1, then the IA can be considered effective, since one unit of the resources provided (inputs) accounts for more than one unit of achieved results (outputs).

Correlation analysis was used to assess the relationship between the resources provided and IA effectiveness. Correlation coefficients were calculated between values of integral indices of inputs and outputs. The regression analysis of panel data was used to assess the degree to which the IA results depend on the resources the region has.

The Results of the comparative analysis of innovation activity in NWFD regions

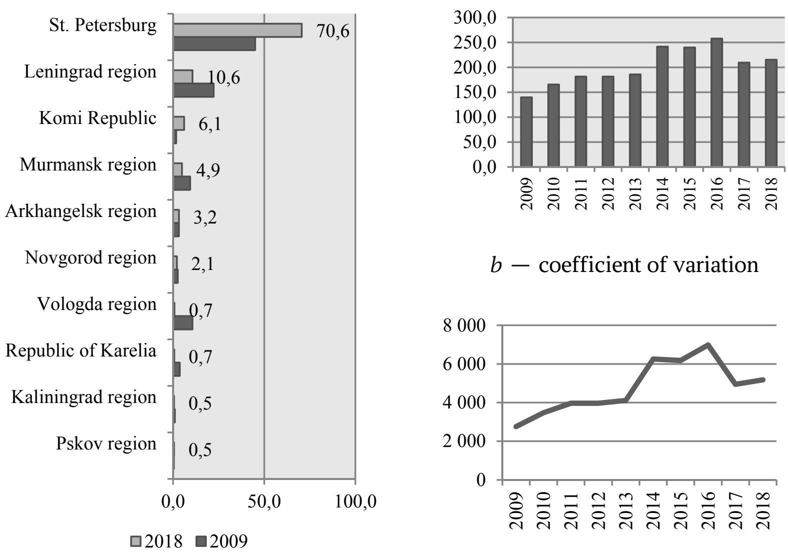
The assessment of IA in the regions of the NWFD was carried out for the period from 2009 to 2018. The study showed that the NWFD is characterized by an uneven distribution of resources and innovation results among its regions. More than 80% of technological innovation costs, internal research and development costs and the number of staff engaged in research and development are concentrated in only two regions: the city of St. Petersburg and the Leningrad Region. The values of the coefficients of variation indicate a high heterogeneity in the distribution of innovation resources, and the Herfindahl-Hirschman index indicates a high degree of their concentration (see fig. 2-4).

A similar situation was noted regarding the key output indicator – the volume of innovative goods, works and services (fig. 5). Another performance indicator, the number of advanced production technologies developed (fig. 6) shows a downward trend in differentiation and concentration (although they remain quite high).

The dynamics of the integrated index of resource provision (fig. 7) clearly reflects the advantage of the northern capital where the IA average value compared with the average for the NWFD is twice as high as in other regions.

The integrated index of the EI results (fig. 8) shows that the northern capital exceeds the average values for the NWFD as a whole by more than 50 %.

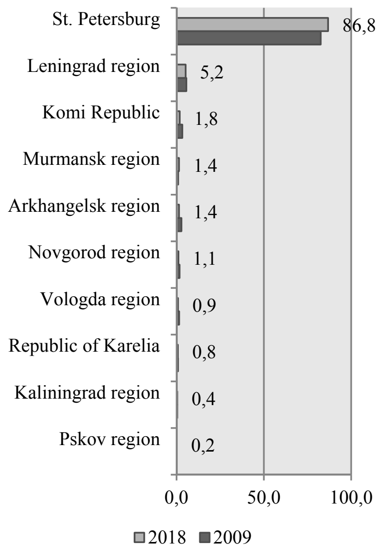
The combination of the values of the integrated indices of resource provision and the effectiveness of the IA allowed building a typology of regions of the NWFD (fig. 9). St. Petersburg is the only city in quadrant III of the complex evaluation matrix. During the given period, the city demonstrated a consistently high level of both resource provision and the ID performance. The remaining regions of the NWFD are mainly concentrated in quadrant I with a relatively low level of both the provision of resources and the effectiveness of IA.

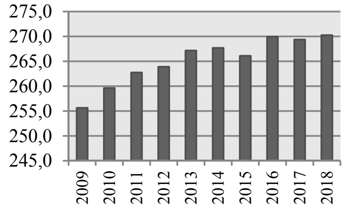


a — the share of regions in the total cost of technological innovations in the NWFD, %

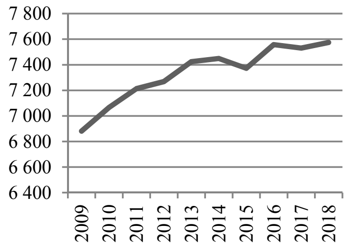
c — Herfindahl-Hirschman index

Fig. 2. Technological Innovation Costs





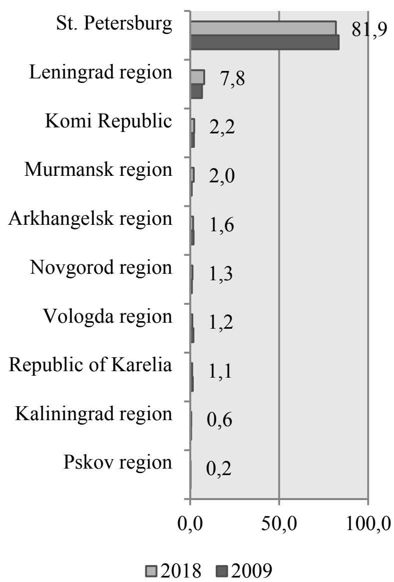
b — coefficient of variation

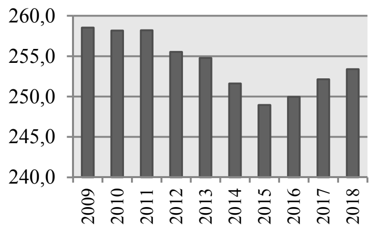


a — the share of regions in the total domestic research and development costs in the NWFD, %

c — Herfindahl-Hirschman index

Fig. 3. Internal research and development costs





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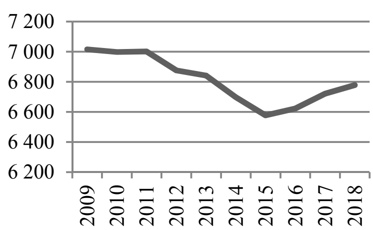
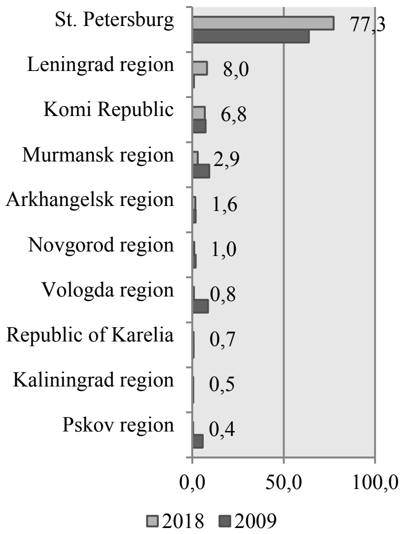
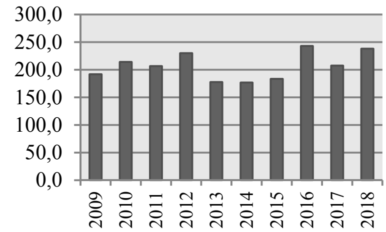


a — the share of regions in the total number of staff engaged in research and development in the NWFD, %

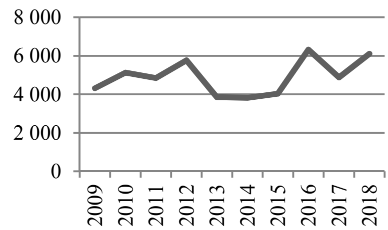
c — Herfindahl-Hirschman index

Fig. 4. Number of staff, engaged in research and development





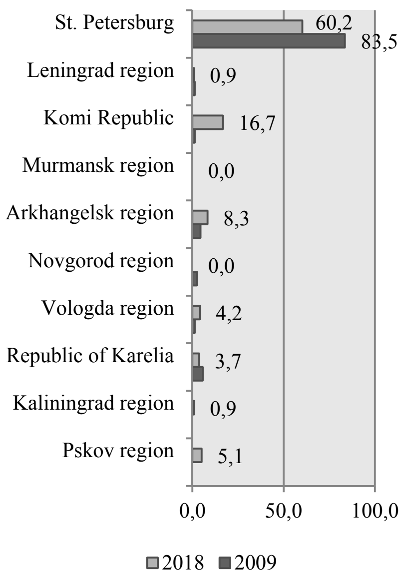
b — coefficient of variation

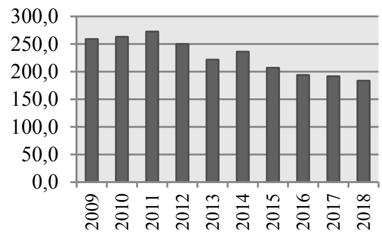


a — the share of regions in the total amount of innovative goods, works and services in the NWFD,%

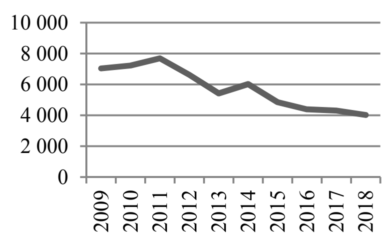
c — Herfindahl-Hirschman index

Fig. 5. Innovative goods, works and services





b — coefficient of variation



a — the share of the regions in the total number of the advanced manufacturing technologies, NWFD, %

c — Herfindahl-Hirschman index

Fig. 6. Number of advanced manufacturing technologies developed

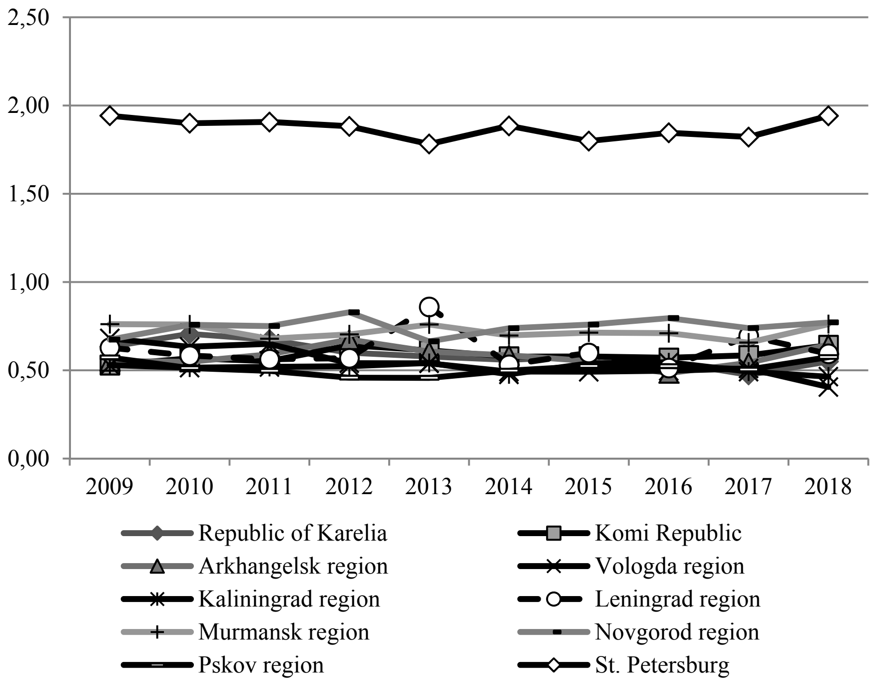


Fig. 7. Dynamics of the integral resource support index IA of the NWFD regions

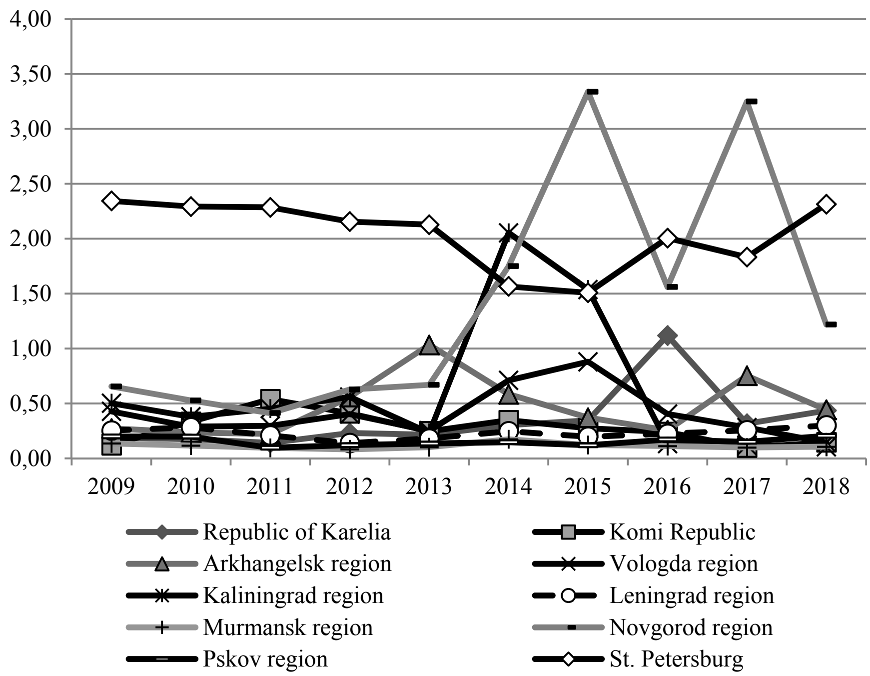


Fig. 8. Dynamics of the integral index of the NWFD results

Of particular note is the Novgorod region: having resources below the average level in the NWFD in recent years, the region has been showing results above the average level. The trajectory of its positions in the complex estimation matrix indicates the vector of motion from quadrant I to quadrant II (Fig. 10).

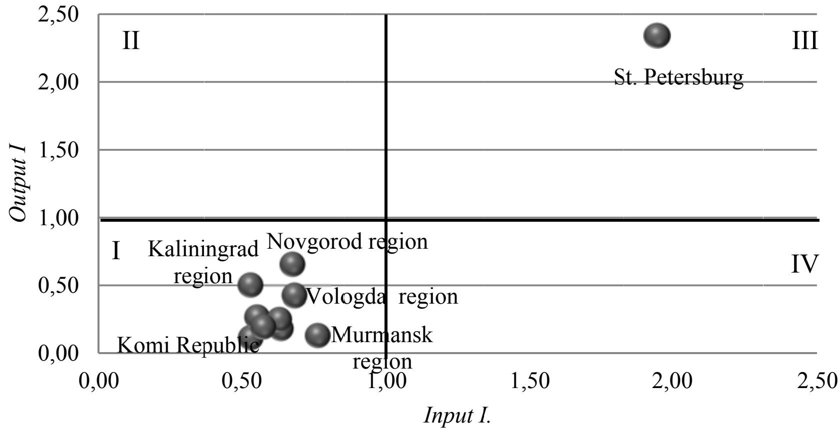
In many ways, the trend in the Novgorod region can be explained by the active position of the regional authorities implementing programmes of socio-economic and information and communication development, actively attracting private investment, developing various forms of public-private partnership [33, p. 870—872], and supporting foreign economic activity. An important factor is the proximity of the region to both capitals, the possibility of 'importing' innovations, scientific and technical integration and targeted support for innovative projects from the federal government. The fluctuations in the position of the region within the second quadrant indicate the necessity to stabilize the results achieved and to develop programmes aimed at ensuring its further progressive dynamics (with subsequent movement to quadrant III).

It has to be noted that the Kaliningrad region, which took a leap forward the same years as the Novgorod region did, was not able to hold its position in quadrant II (Fig. 11). This can be explained by the lack of necessary resources. Since 2015, the region has been experiencing a significant decline in both the number of scientific organisations and the number of research staff, accompanied by a drop in the total cost of technological innovation and, as a result, a significant decline in the number of advanced production technologies developed. By mid-2016, the cost of innovation had fallen 2.5 times, and the number of intellectual property objects used by enterprises of the region had halved. The lack of business ownership in the creation of R&D has exacerbated the situation [34]. The current situation explains the decrease in the effectiveness of the region's IA in recent years.

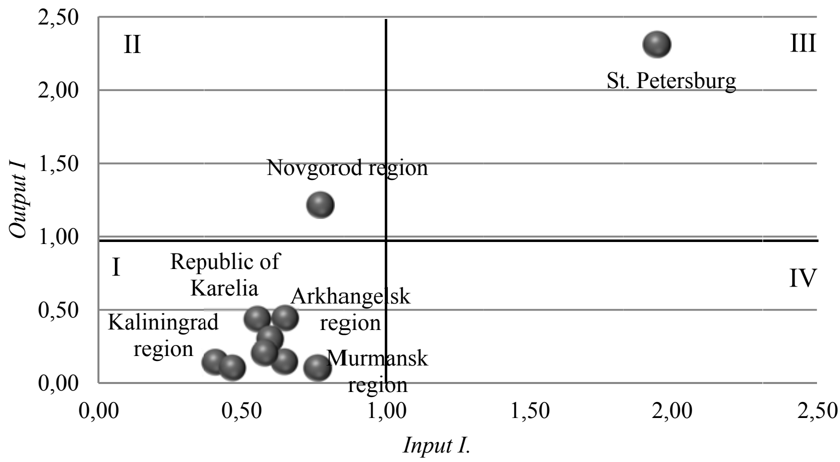
A similar situation, but in a less pronounced form (a leap in performance above the average) was observed in the Arkhangelsk region in 2013.

Table 1 shows the correlation of the values of integral indices of inputs and outputs of IR regions with the index of conditional efficiency of ID.

The comparison of the positions of regions in the matrix and the indicators of conditional efficiency of ID allows a conclusion that there is a correlation between the positions of regions in the matrix of complex assessment and the index of conditional efficiency. The regions with low resource provision generally demonstrate not only low ID efficiency (quadrant I), but also low effectiveness. Regions moving to quadrant II show high innovation performance. The only region located in quadrant III (St. Petersburg) is characterized by a relatively high conditional efficiency of the ID with its high resource provision.



a — 2009



b — 2018

Fig. 9. Comprehensive assessment of ID of the NWFD regions

The correlation analysis revealed a high degree of interaction between resource provision and innovation performance in the NWFD regions (the coefficient of paired correlation between the corresponding integral indices was 0.6838).

Regression analysis of panel data was performed using the econometric package Gretl. Since the composition of the NWFD regions is fixed, two types of models were used: a model with fixed effects and a regular MNK model (pooled regression model). The analysis included 10 spatial objects (regions of the NWFD). The length of the time series was 10 years. Thus, the total number of observations was 100. In modeling, robust standard errors were used.

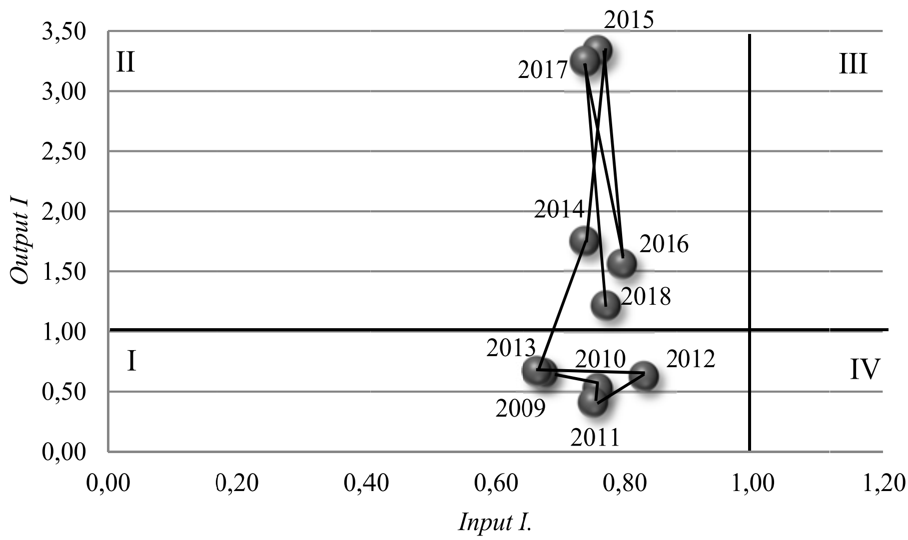


Fig. 10. Position trajectory of the Novgorod region
in the complex evaluation matrix

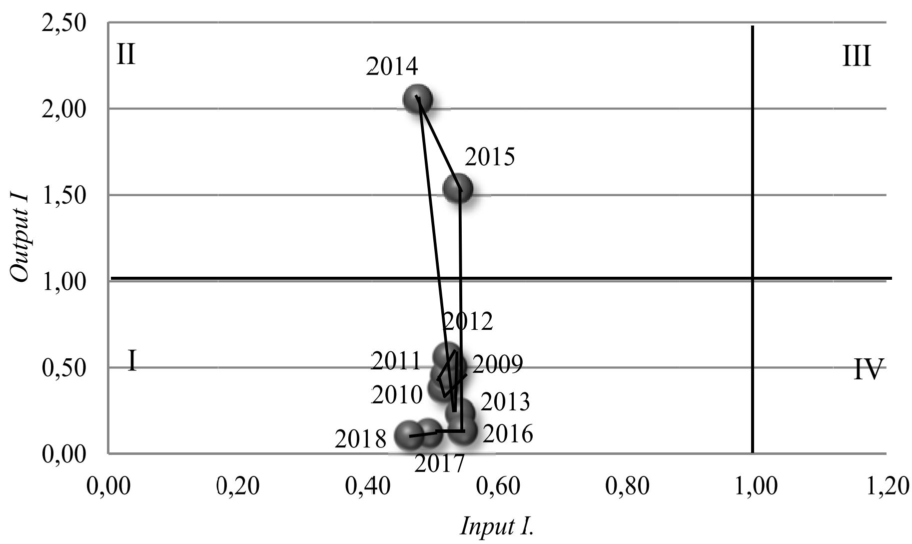


Fig. 11. Position trajectory of the Kaliningrad region
in the complex evaluation matrix

Table 1

Conditional efficiency of innovation development (ID) of the NWFD regions

Region	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Republic of Karelia	0.41	0.40	0.29	0.37	0.42	0.53	0.54	**1.48***	0.67	0.74
Komi Republic	0.64	0.95	**1.03**	0.59	0.84	0.88	0.95	0.71	0.46	0.47
Arkhangelsk region	0.74	0.75	0.67	**1.04**	**1.53**	**1.02**	0.79	0.84	**1.28**	0.74
Vologda region	0.70	0.62	0.56	0.83	0.56	**1.16**	**1.40**	0.80	0.61	0.39
Kaliningrad region	**1.25**	0.88	0.99	**1.21**	0.85	**3.28**	**2.24**	0.56	0.47	0.41
Leningrad region	0.94	0.99	0.90	0.85	0.52	0.87	0.74	0.98	0.69	0.95
Murmansk region	0.68	0.63	0.55	0.51	0.50	0.64	0.52	0.52	0.50	0.35
Novgorod region	1.34	0.97	0.80	0.79	0.95	**1.77**	**3.06**	**1.47**	**2.98**	**1.21**
Pskov region	0.33	0.40	0.27	0.28	0.41	0.38	0.30	0.37	0.37	0.41
St. Petersburg	**1.02**	**1.03**	**1.06**	**1.03**	**1.07**	0.84	0.86	**1.01**	0.99	**1.12**

* In bold, the conditional efficiency values equal to 1 and > 1.

When comparing the integral indices of inputs and outputs of the NWFD regions, the model with fixed effects showed the statistical insignificance of spatial effects so the following MNK model (pooled regression) was built (standard errors are indicated in parentheses):

$$\hat{}l\_Output\ I = -0{,}074 + 0{,}491 \cdot l\_Input\ I + 0{,}559 \cdot l\_Output\ I\ (-1), \qquad (5)$$
$$(0.0344) \qquad (0.0432) \qquad (0.0478)$$

where ^l_Output I is the logarithm of the integrated performance index ID (assessment); l_Input I — the logarithm of integrated index of resource provision of ID; l_OutputI (–1) is the logarithm of the integral index of the ID performance with a one year lag.

The model is statistically significant, the parameters l_Input I and l_Output I (–1) are significant at a 1% level, the constant is significant at a 10% level. The co-determination coefficient is 0.722, the p-value of the F-test is 2.84e-12, which indicates the statistical significance of the equation. The Ramsay test confirmed the correctness of the model specification; the test for normal distribution showed that errors are distributed according to the normal law. The value of the dispersion bloating factor showed no multicollinearity in the model.

It follows from the equation that the performance of the ID regions of the NWFD depends directly on the resource provision and the results achieved earlier. At the same time, an increase in the provision of resources by 1% will lead to an increase in the efficiency of the ID by 0.5%; and a 1% increase in efficiency in the last period ensures its growth in the current period by 0.6%.

Modeling the dependence of the key result of innovation, which is the amount of innovative goods, works and services, on the factor variables of inputs showed that in terms of parameters the MNK model (a model with fixed effects again revealed their statistical insignificance) of the following type was the best:

$$\hat{}l\_ITRU = -0{,}148 + 0{,}381 \cdot l\_ZTTI + 0{,}599 \cdot l\_ITRU(-1), \tag{6}$$
$$(0{,}136) \qquad (0{,}132) \qquad\qquad (0{,}118)$$

where ^ l _ ITRU is the logarithm of the standardized value of the volume of innovation goods, works and services (assessment); l_ZTTI is the logarithm of standardized cost of technological innovations; l_ITRU (−1) is the logarithm of the standardized value of the amount of innovative goods, works and services with a lag of one year.

The model is statistically significant, the parameter l_ZTTI is significant at 5% level, the parameter l_ITRU (−1) is significant at 1% level. The determinant coefficient is 0.6470, the p-value of the F-test is 2.60e-07, which indicates the statistical significance of the equation. The Ramsay test confirmed the correctness of the model specification, the test for normal distribution showed that the errors are distributed according to the normal law. The value of the dispersion bloating factor showed no multicollinearity in the model.

It follows from the equation that the efficiency of the volume of innovative goods, works and services produced in the regions of the NWFD depends directly on the costs of technological innovation and the results achieved earlier. At the same time, a 1% increase in costs of technological innovation leads to an increase in the amount of innovative goods, works and services by 0.38%, and a 1% increase in the amount of innovative goods production in the last period ensures its growth in the current period by 0.60%.

Discussion and conclusions

The method of comparative evaluation of IA proposed by the authors makes it possible to assess the differences in the innovative development of regions of the NWFD, the dynamics of their comparative positions in resource provision, and the effectiveness of innovation activity. The method proves to be effective in determining the type of a region, as well as factors influencing the dynamics of its development over several years. The study makes a scientific and methodological contribution to the development of the evaluation apparatus of innovation theory.

The practical significance of the proposed method has been proved by the results of its application. It allowed revealing the features of innovative development of the regions of the North-Western Federal District, the main ones being the extreme non-homogeneity of the distribution of resource provision and the results of innovation activities (St. Petersburg and the Leningrad region account for the vast majority of them). The analysis of the integral resource indices and the EID results allowed a typology of the studied regions according to the resources spent and the results obtained. The study has also found that most NWFD entities exhibited low innovation efficiency. The city of St. Petersburg was the leader in efficiency and effectiveness during the whole period under study. A dynamic positive trend towards increasing the efficiency and effectiveness of innovation was observed in the Novgorod region.

The authors' analysis of the Volga Federal District (VFD) [35] showed high unevenness of distribution of the resources and results of innovative activity of the regions. This unevenness was indicated by the positions of the regions in the corresponding quadrants of the matrix of complex estimation. A significant difference was that in the NWFD, unlike the VFD, there were no regions having a relatively high level of resource provision that would show a relatively low performance of innovation activities. In addition, the regions of the VFD are characterised by higher instability of the values of integral indices in comparison to those in the regions of the NWFD.

It should be noted that sharp fluctuations in indicators of conditional efficiency of the ID regions (Table 1) are due to the instability of indicators of its resource provision and the efficiency in dynamics. Thus, when conducting a comparative assessment, a sharp increase in the impact of ID in one region will automatically lead to a marked decrease in performance indices in other regions. This can serve as both the advantage and the disadvantage of the proposed methodology. The disadvantage is the impossibility of conducting an automatic assessment of the efficiency and effectiveness of the ID in each region, and the advantage is the continuous comparison of the resource provision and efficiency of the ID in the region with other regions of the district. This comparison helps regional authorities to develop strategically correct solutions aimed at maintaining or increasing the rating positions of their own region, taking into account the dynamics of positions of other regions of the district.

Correlation-regression analysis based on panel data has shown a significant positive relationship between ID performance and its resource provision in the NWFD regions. The model of the dependence of the volume of innovative goods, works and services on the factor variables of the inputs has shown that the greatest impact on the result was by the costs of technological innovation and earlier results. It emphasises the importance of sustaining innovative development in the regions and regular investing in the improvement of production processes and technologies.

In case the resources for innovation are limited, it is important that the results achieved in one of the regions are available for implementation and use in other regions. This would enable low-resource regions (quadrant I) to increase the impact of their innovation activities (move to quadrant II) by using the results created in high-resource regions (quadrant III). Such a positive synergy effect could be a significant incentive for the development of the entire NWFD as a single administrative-territorial system. In this context, the coordination of innovation development programs is very important, which would provide not only the creation but also the implementation of innovations beyond the territory of the constituent entity of the Russian Federation that had generated them.

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